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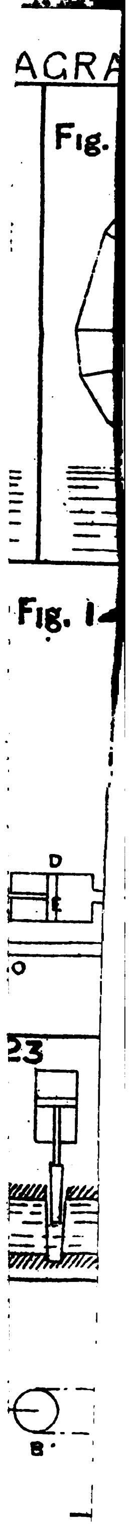

ADAMS

ON

HYDRAULIC MACHINERY.

LONDON:
F. W. POTTER AND Co., 17, QUEEN VICTORIA STREET, E.C.

REPRINTED, 1885.

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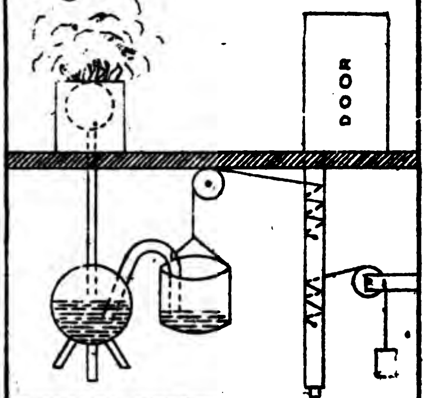
Fig. 1



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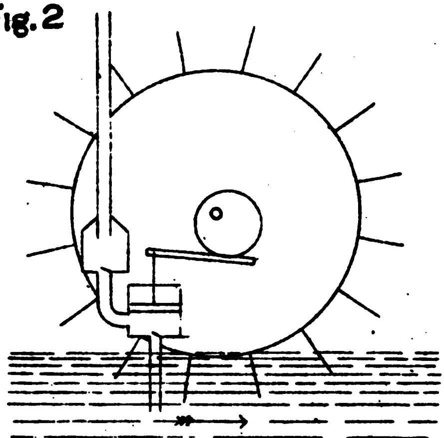

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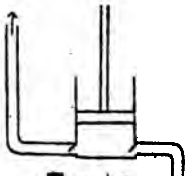

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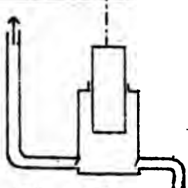

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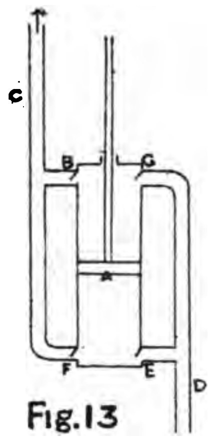
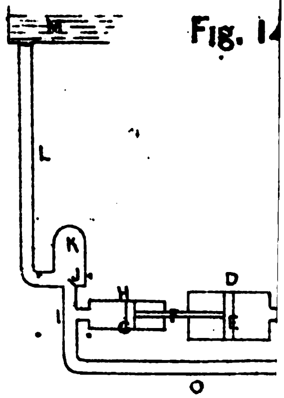


Fig. 13

Fig. 14



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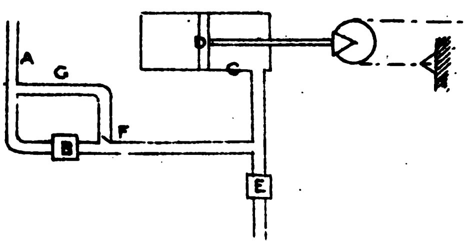

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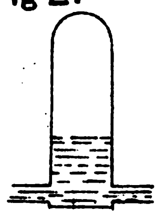

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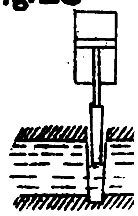

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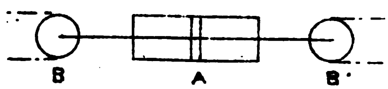

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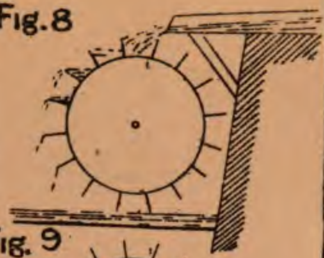

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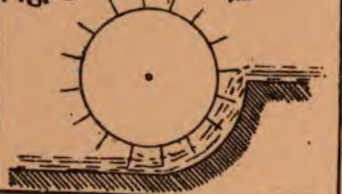

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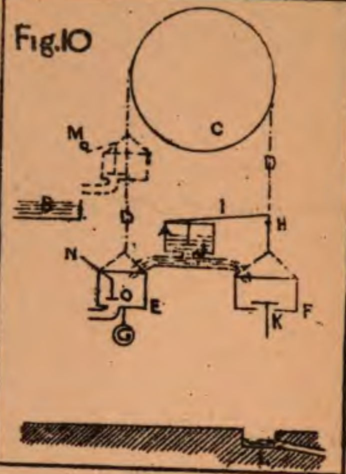

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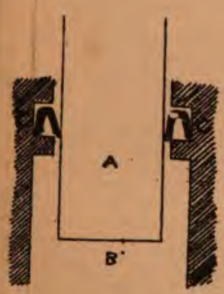

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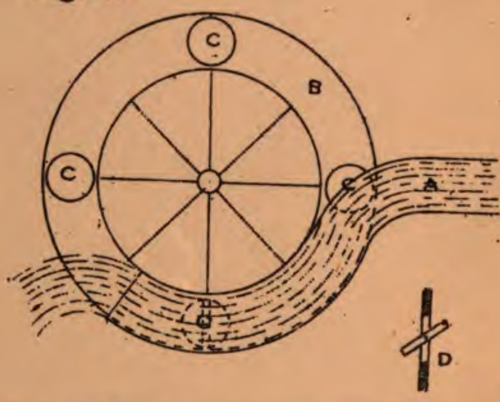

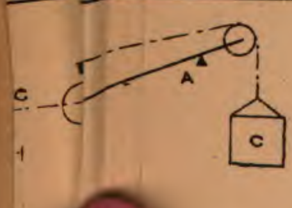

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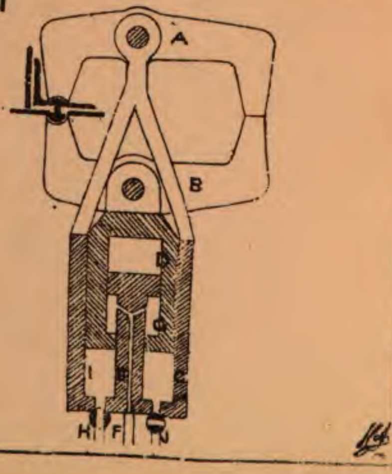

HYDRAULIC MACHINERY,

PAST AND PRESENT.

A LECTURE

DELIVERED TO THE

LONDON AND SUBURBAN

RAILWAY OFFICIALS' ASSOCIATION,

On the 10th January, 1880,

BY

HENRY ADAMS, M. INST. C.E.,

Consulting Engineer

and

Professor of Engineering at the City of London College.

REPRINTED—1885.

F. W. POTTER & Co., STEAM PRINTERS,

17, QUEEN VICTORIA STREET, E.C.

London and Suburban Railway Officials' Association.

ESTABLISHED 1873.

Registered as a Specially Authorized Society, under the Friendly Societies' Act, 1875, *on the first day of January,* 1878.

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London and Suburban Railway Officials' Association.

PROSPECTUS.

The progress of railways of late years has been such as far to exceed the most sanguine expectations. If we take a glance at the railways in and near London, we find tunnels made, bridges, viaducts and signals erected, permanent ways, with all their points and crossings laid down, stations, warehouses, and workshops built, engines, carriages, waggons, turntables, and almost every description of machine constructed to meet the demand and to futher develope the railway traffic. We also find every class of Officer and Man employed and actively engaged in the various departments to meet the requirements and conduct the business of a dozen railway companies. It is remarkable, with so many railways within the London District, that the officials engaged on one line have hitherto had scarcely any knowledge of those holding similar positions on others, and with these facts before us, we consider the time has arrived when the officials of the London and Suburban Railways should become acquainted, and with that view this Association has been formed. We are aware that many railway officials (especially in the mechanical branches) are already enabled to become members of societies according to their profession, while many others equally valuable, holding positions of great responsibility in the service, are not eligible to join them. It is therefore the intention of this Association to admit any railway official to be a member within the London and Suburban District (in accordance with the rules), irrespective of trade or calling, and as far as possible to unite in fellowship and good will, and assist each other in the maintenance of position and respectability, which we feel assured will establish that confidence among railway officials requisite for the good management of every department, and benefit of railway service generally. We have also something more to add, and although last, we think it not least in importance, viz.:—To provide a fund to assist members when out of situations, or when age or infirmity have incapacitated them, and at their decease to meet the claims as set forth in the rules, and to render such other assistance as may be deemed advisable.

In establishing this Association, we would much prefer to subscribe than receive, yet at the same time we consider it our duty to be prepared to assist, or be able to obtain assistance if needed. We therefore kindly ask the co-operation and assistance of those gentlemen who are connected with or may feel interested in the progress of railways, by adding their names as Honorary Members or Donors to the "London and Suburban Railway Officials' Association."

London and Suburban Railway Officials' Association.

Meeting of Association, held at the Mansion House Station on Saturday, 10th January, 1880.

The PRESIDENT, WILLIAM ADAMS, ESQ., in the Chair.

The President introduced Mr. HENRY ADAMS, who then delivered the following Lecture on

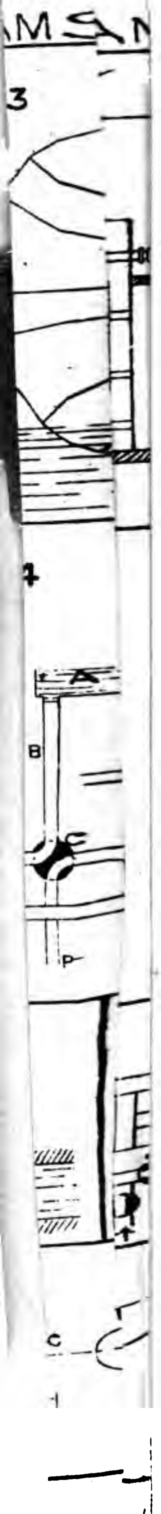
HYDRAULIC MACHINERY—PAST AND PRESENT.

MR. PRESIDENT AND GENTLEMEN,

In preparing the following notes, I have assumed that a majority of your members are unacquainted with the details of the application of hydraulic power, and I have therefore confined my illustrations to simple outlines, which indicate the principles, but do not show the exact detail employed.

Hydraulic machinery may be defined as mechanism actuated by water for the purpose of raising a load or doing any other mechanical work.

Long before the appearance of man on the earth, water was the great transporting medium which carried trees and stones down from the hills to the ocean, and it was also the first source of inanimate motive power controlled and directed by the ingenuity of mankind. Water alone might form the subject of many discourses. In the dawn of civilization it was reverenced by philosophers as the life-giving principle of the universe; and even in the present day shoals of pilgrims are to be seen travelling to the Ganges, the sacred river of



India, to worship the self-same substance. With these people it is deemed a virtue to think of the river, while to bathe in its waters washes away all sin, and to expire on its brink, or be suffocated in its embrace, is the climax of human felicity.

We are, however, concerned only with the practical application of the good qualities resident in the water. We shall find three of these very useful in their bearing upon the question before us, viz., its gravity or weight, its momentum or moving force as in a running stream, and its mobility combined with resistance to compression, which render it so valuable in transmitting power to long distances.

The subject is a large and important one, and is destined to become of still greater importance. Its rapid progress in recent times is apt to lead one to suppose that machines actuated by water are of modern origin, but ancient writers tell us that Archytas, of Tarentum, invented hydraulic machinery about the year 400 B.C.; no description of his inventions has reached our times, but we have records extending nearly as far back. Hero, a celebrated mechanician of Alexandria, who lived over 2,000 years ago, among other works wrote a treatise on Pneumatics, in which he described several curious devices handed down by former writers, whom he at that time called "ancient philosophers." Among these devices is one in which water is caused, by its weight, to effect the opening of a temple door.

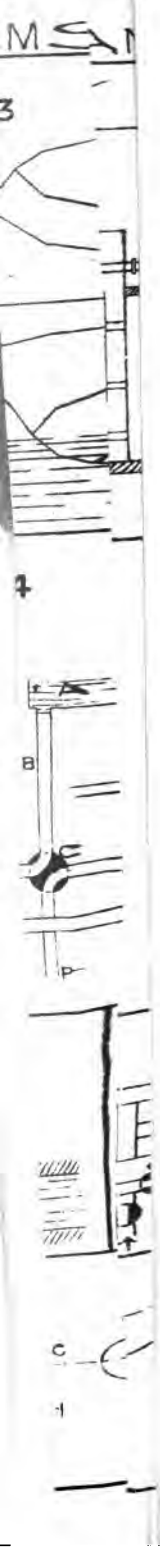
Although the method is clumsy, it is certainly ingenious, and I shall endeavour to describe it to you, with the aid of a diagram (Fig. 1).

In the upper portion of the sketch we have the interior of a temple, with a door on the right and an altar on the left. The altar contains an air-tight receptacle in such a position that it will be subject to great heat as soon as a fire is lighted. This receptacle communicates by a pipe with a larger receiver partly filled with water, and placed in the basement, or any excavation below the temple floor. A syphon pipe leads from this receiver into a bucket hanging to a cord, which passes over a pulley, and is wound round a

shaft firmly secured to the door above, and pivoted at the bottom. Attached to this shaft is another cord wound in the opposite direction, passing over another pulley and supporting a weight. The action of the apparatus is this:—When a fire is kindled on the altar, the air-receiver under it is heated, the air expands, and passing down the pipe, presses on the water in the large receiver, forcing it through the syphon pipe into the bucket. As soon as sufficient water has entered the bucket to overcome the resistance of the suspended weight and the friction of the door, the bucket begins to lower, and, pulling on the cord wound round the upright shaft, opens the door and raises the weight. The apparatus is so proportioned that as the water pours into the bucket and the bucket lowers, the mouth of the syphon pipe keeps just below the level of the water, and the bucket reaches the ground before the pipe is quite withdrawn. When the temple services are concluded and the fire extinguished, the air-receiver cools down, the air in it contracts and causes a partial vacuum in the large receiver, and the water flows back into it from the bucket. The weight has more power than the empty bucket, and now lowers, turning the shaft round and closing the door. Of course this piece of mechanism below the floor, if ever used, formed part of the esoteric religion, and no vulgar eyes were allowed to see by what earthly means the gods signified their approval of the burning sacrifice by mysteriously opening to them the temple door.

Wheels, partly immersed in a running stream, and receiving motion from it, formed so ancient a device for obtaining power, that we have no record of their origin, but it is not generally known that force pumps worked by water wheels date back nearly so far as they unquestionably do. The following anecdote, for which I am indebted to Thomas Ewbank's admirable book on raising water, will show you how and when this force pump arrangement received its last and most important addition—that of an air vessel:—

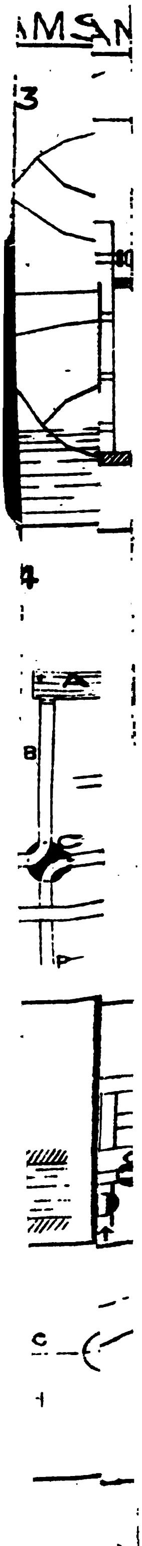
About the year 200 B.C., during the reign of Ptolemy Philadelphus over Egypt, an Egyptian barber pursued his vocation in the city of Alexandria. Like all professors of that ancient



mystery, he possessed, besides the inferior apparatus, the two most essential implements of all—a razor and a looking-glass or mirror, probably a metallic one. This mirror, we are informed, was suspended from the ceiling of his shop, and balanced by a weight, which moved in a concealed case in one corner of the room. Thus, when a customer had undergone the usual purifying operations, he drew down the mirror that he might witness the improvement the artist had wrought on his outer man, after which he returned it to its former position for the use of the next customer. It would seem that the case, in which the weight moved, was enclosed at the bottom, or pretty accurately made, for as the weight moved in it, and displaced the air, a certain sound was produced, either by its expulsion through some small orifice, or by its escape between the sides of the case and the weight. This sound had probably remained unnoticed, like the ordinary creaking of a door, perhaps for many years, until one day, as the barber's son was amusing himself in his father's shop, his attention was arrested by it. This boy's subsequent reflections induced him to investigate its cause, and from this simple circumstance he was led eventually either to invent or greatly to improve the hydraulic organ, the force pump, the air gun, fire engine, &c. Now this barber's son was Ctesibius, of Alexandria, one of the most eminent mathematicians and mechanicians of antiquity, and the teacher of Hero, of Alexandria, of whom I have previously spoken. No illustration of the pump of Ctesibius has survived, but from the descriptions handed down it is supposed to have been constructed as shown in our next diagram (Fig. 2.) A wheel having projections or float boards on its rim is placed in a stream; fixed upon the same shaft with the wheel, and therefore revolving with it is a piece called a cam, which stands out more on one side of the shaft than the other. At each revolution this pushes down one end of a lever, to the other end of which is connected the pump rod, carrying a solid piston closely fitting the barrel of the pump. In the bottom of the pump is a suction-valve and a pipe leading to the water, and in the side another

pipe, terminated by a delivery valve at the bottom of an air vessel. Inserted in the air vessel is a delivery pipe, up which the water passes to its destination. The air vessel is in effect an elastic cushion, compressed during the stroke of the pump, and expanding during the return stroke, so that the water is forced up the delivery pipe in a continuous stream. In some cases there were two pumps worked by the same wheel and connected to the same air vessel to still further equalise the flow. In the diagram no details are shown, but the mechanical arts must even at that time have arrived at some degree of perfection, for we are told that "the cylinders were made of brass, the pistons turned very smooth, and the valves hinged with very exact joints."

About the beginning of the Christian era, a Roman architect and engineer, named Vitruvius, wrote a treatise on those professions, and inserted a brief account of the hydraulic machines then in use. Among them we find the tympanum, a kind of water-wheel so formed as to lift a portion of the water in which it revolved. This is shewn in our next illustration (Fig. 3). The wheel is pushed round by the force of the current, while the arms, formed like open gutters or troughs, scoop up the water, which runs towards the axle as the arms reach a horizontal position. The axle is a hollow pipe having openings to each arm, and its end communicates with a channel over the bank of the stream, whence the water is conveyed away for irrigation or other purposes. When it was desired to raise the water higher than this, another form of wheel was used. It is shewn in Fig. 4. This consists of a wheel with floats or paddles to allow of its propulsion by the stream, and with square boxes attached to the side of the rim. These boxes have an opening, by which the water is *admitted* while they are passing through it, and *discharged* when they reach the top, into a trough fixed in front of the wheel. The Chinese use wheels of the same description as this, constructed of bamboo, and, according to one writer, some are as large as 70 feet in diameter and raise over 300 tons of water in 24 hours. Of course, if you asked them, the Chinese would claim to be the original inventors



of this wheel, as they do of gunpowder, telephones, and everything else, but the popular name in antiquity is the Egyptian wheel.

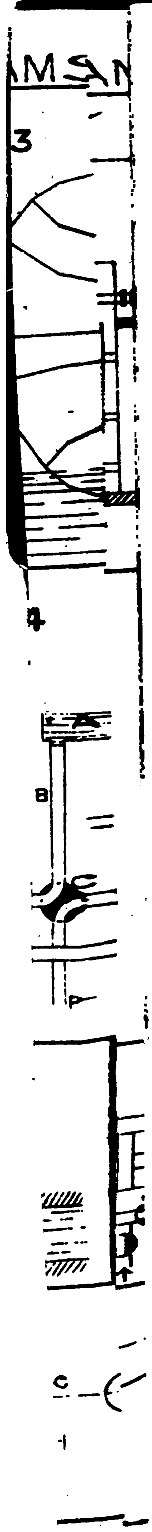
We do not often hear of Persia producing anything novel, but in this case a decided improvement on the last example is attributed to that nation. The fixed boxes or buckets have the disadvantage of discharging part of their contents before they quite reach the top, and so waste some of the water; in the Persian wheel the buckets are hung on pivots, and overturned into a trough on reaching the top by striking against a projecting pin. In connection with these wheels it is interesting to note, firstly, the defect common to them all, of lifting the water at the outer end of the arms, and therefore in the position to require the greatest expenditure of power; and, secondly, the improvement introduced by a French philosopher, M. De la Faye, about 150 years ago, solely from geometrical reasoning. He designed a wheel with hollow curved arms between two discs, the curves being of the shape known as involute. This is shown in the next diagram (Fig. 5). In this arrangement, as the wheel revolves, the water flows up the arms, remaining nearly under the centre, until lifted to the axle through which it flows, as in the tympanum. The effect of adverse leverage is thus entirely obviated, and a great saving in power effected. Still better than this was the invention of Wirtz, a Swiss pewterer, in 1746, who by making one continuous spiral, taking in air and water at each revolution, was enabled to raise the water to a great height, in one case 74 feet.

On the Continent water-wheels connected with pumps were used for elevating water after the style of Ctesibius, many years before the introduction of the same thing to England.

In the year 1582 Peter Maurice, a German engineer, proposed to erect a similar machine in London, for supplying water to the houses. The Lord Mayor and Common Council were so pleased with the proposal that they granted the use of one of the arches of the London Bridge of that time, in which to place the machinery. It consisted of a series of force pumps 7 inches in diameter and 30 inches stroke, worked by an undershot water-wheel turned by the current

during the rise and fall of the tide, raising the water to a height of 120 feet. This machinery was repaired and extended from time to time until it was finally removed in 1822, after it had long done good service to the citizens of London. A most elaborate pumping arrangement of this description was erected in 1862 on the Seine near Paris. It consisted of 14 large undershot water-wheels working 250 pumps at various elevations, raising the water to a total height of 530 feet. The water was lifted in stages, the higher pumps being worked by cranks and chains led from the water-wheels. This machinery was in use over a hundred years, but had many alterations tried, and was never satisfactory, owing to the great mistake of not doing all the work at one lift by having smaller pumps and stronger pipes. Finally falling into decay, it was replaced by order of Napoleon with a steam pumping engine.

Nearly all the early applications of water as a motive power with which we are acquainted had for their object the raising or distributing of water; no doubt other applications were invented, but they do not seem to have had any extended use. Although apparatus connected with water-wheels is the oldest form of mechanism of this class, yet we have a few examples of more direct method. Fludd, an English astrologer and alchymist, in 1618, described in one of his works a form of pumping engine, which it is supposed he saw in use in Germany during his travels there. Its pecularity is that it allows a foul source of supply to become the agent for raising a pure supply. Its interest to us is, that it is the oldest piston pressure engine known. The arrangement is shown on our next diagram (Fig. 6). A is the impure water, with a pipe B leading from it; at a certain distance is a cock C, and the lower end D is open. From one side of the cock C a pipe F leads to the pump cylinder G, having a solid piston H free to slide up and down. Leading from the top of the cylinder is a short pipe communicating with the suction pipe I, entering the well or pure water supply J, and having a suction valve at K and a delivery valve at L. The upper end of this pipe terminates in a cistern or reservoir M



for the pure water. The cock C, instead of having an ordinary straight passage through it, has a right-angled or elbow passage in the plug, and three outlets in the casing, making it what is commonly known as a three-way cock. The action of the apparatus is as follows:— The three-way cock being in position shewn, the lower outlet D is shut off, the water from A passes through pipe F to cylinder G, and pushes up the piston H, forcing any air or water that may be above it into pipe I; the valve K closes by the pressure in the pipe, but that at L opens, allowing the the air or water to pass up into the cistern M. By a very simple self-acting arrangement, which I will describe presently, the position of the three-way cock is reversed, assuming the direction shewn in the side sketch N; the water below piston H now passing back again through C and out at D. The piston in lowering creates a partial vacuum above it, and the pressure of the air on the surface of the water in the well J now forces some of the water up through valve K into the pipe I and upper part of the cylinder. The three-way cock again comes back to its first position, and the water from A passes through B C and F to lift H and forces the water above it through L into M as before. The reversal of the three-way cock is effected by the lever O having a weight at one end and a small bucket at the other. The pipe B, which is always standing full of water, has a short open-ended branch P in such a position that a jet is just directed into the empty bucket, filling it during the time the water is pushing the piston up in the cylinder, both these operations being completed at the same time. The full bucket now overbalances the weight and lowers down away from the jet on to a projecting peg, which opens a valve in the bottom and lets the water out, so that the weight may bring it up as before.

Gaspar Schotti, one of the Jesuit Fathers, wrote in Latin in the year 1664 a remarkable book entitled " Technica Curiosa," or Technical Curiosities. I happen to possess a copy of this work, and shall be happy to shew it to you at the close of the lecture.

In this book, among a multitude of curious old contrivances, is given an account sent to his author in 1661, by Lord William Schroter, of an invention from Holland for "emptying out stagnant water." It is described as a descending weight acting upon gearing which causes a water-wheel to revolve and force the water away, the weight being raised again by means of a small crab winch worked by one man. It appears to me that Father Schotti has fallen into an error here, and that he has reversed the operations—in fact, made the cart pull the horse along. I have shewn in outline at Fig. 7 the arrangement illustrated in the book, and my explanation of it is, that the object of the inventor was to devise a means of raising goods in a waterside warehouse. You will observe a water-wheel partly immersed in the water, which I assume to be a running stream; on the same shaft is fixed a small wheel working into a larger one; the large one carries on its shaft another small wheel, which again works into a second large wheel. On the same spindle is another small wheel working into a third large one. This third wheel is connected to a shaft in the building by a clutch, which is an arrangement for making or releasing the connection at will. Attached to a drum on this shaft is a rope by which a sack of corn is being raised. Upon the sack reaching the floor required, the clutch is put out of gear, the sack disconnected, and the rope lowered either by the small crab referred to or by means of its own weight. Here we have a clear and definite arrangement suited to the purpose, and I venture to put it forward as the first practical application of water power to the raising of heavy weights.

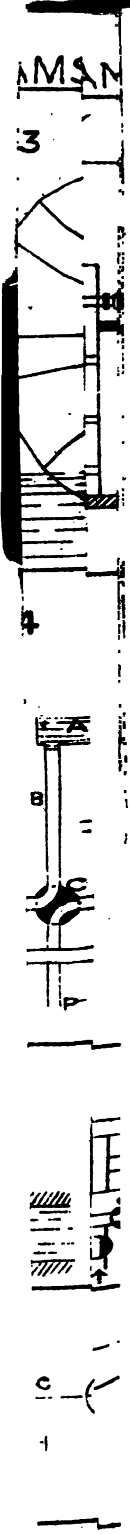
All the wheels previously illustrated belong to the class known as undershot, the motive power being only the force due to the rapidity of the current, but there are two other typical forms which are used as prime movers, known respectively as overshot and breast wheels (Figs. 8 and 9). In these the weight of the water is utilised as well as its velocity, and according to the circumstances of the case so one or other of them can be adopted. Horizontal water-wheels driven by a current of water directed against the floats are said by Mr. Glyn, in his little

treatise on the power of water, to have been the first kind used to drive corn mills. It would be interesting, but would occupy too much time, to trace the development of these into the modern turbine. In the primitive form the water was simply directed on a level against flat vanes or paddles; then the paddle boards were curved and became buckets; then the water was directed downwards at an inclination, striking the wheel from above, the buckets being inclined as well as curved, so that the weight of the water as well as its momentum was made to assist. Next the buckets were continued to the centre, forming curved arms or blades; then a second fixed wheel was added to guide the water on to the moving wheel in the best direction, and lastly the whole arrangement was enclosed so that the water might be brought down in an enclosed pipe from any height, and the whole of it used in producing useful work.

In the year 1665 that celebrated amateur mechanic, the Marquis of Worcester, wrote his "Century of Inventions," and among these we have one (No. 21) described as follows (*sic*):—"How to raise water "constantly with two Buckets onely by day and night, without any "other force then its own motion, using not so much as any force, "wheel or sucker, nor more pullies then one, on which the cord or "chain rolleth with a Bucket fastened at each end. This, I confess, I "have seen and learned of the great mathematician Claudius his studies "at Rome, he having made a present thereof unto a Cardinal; and I "desire not to own any other mens inventions, but if I set down any, "to nominate likewise the inventor." The Marquis of Worcester seems to put all his descriptions in the form of enigmas, and as he gives no illustrations, we are free to form our own opinions as to the actual arrangement he proposed. Mr. Dircks, from whose edition I make this extract, gives an illustration of an endless chain of buckets which I do not consider warranted by the description. I think there is no doubt that this is the device known as the "Roman automatic buckets" also described by Father Schotti. He says one was fixed in the convent of Santa Maria de Victoria, but, from its perpetual motion and noise disturbing the monks, it was destroyed. The principle

of this machine is shewn in the next diagram (Fig. 10). At A we have the end view of a trough or channel containing water derived from a natural source, and at B we have a tank at a higher level, to which the water is required to be raised. At C is a large wheel or pulley with a chain or rope D D passing over it; attached to the ends of the chain are two buckets E and F, so proportioned that when empty, the small one E is heavier than the other by reason of a weight G attached to it, but when full the larger quantity of water contained in F is sufficient to overbalance the small bucket with its contents and the counter-weight. The action of this machine is as follows:—In the position shewn in the diagram the small bucket has just lowered and raised the large one, so that the tappet H on the chain D has lifted the lever I and opened the valve J, allowing the water to pass through the branched pipe to fill both the buckets. When full the large bucket descends, removing the tappet H from the lever, and allowing the valve to close to prevent loss of water. Upon nearly reaching the ground the valve with projecting stem K is pushed open, and the water escapes through the bottom into the drain L. At the same time the bucket E is lifted as shewn by dotted lines, until the projecting pin M catches the lever N and opens the valve O, allowing the water to pass out into the upper tank. When both buckets are empty you will remember the smaller one is the heavier and it then descends, raising the large one until the tappet H again lifts the lever I and opens valve J to fill the buckets as before. The apparatus is thus self-acting, and forms one of a group of machines from which the water-balance hoists of the present day are derived.

Force pumps were known to the ancients, certainly from the time of Ctesibius; the form generally used was that of a piston attached to a rod, working in a cylinder with an open top, as shewn in Fig. 11, but it is probable that there were instances similar to Fig. 12 of the use of an enlarged piston rod without a piston, the top of the cylinder being contracted to fit the rod, and the other part of the cylinder enlarged to avoid the difficulty of



boring it out. Although old illustrations exist which may be taken to indicate this form, its introduction is not certain until 1675 when Sir Samuel Moreland, master of mechanics to Charles II., obtained a patent for it.

In 1718 the double-acting pump was devised by a Frenchman named La Hire, by which means the same size cylinder was enabled to supply double the quantity of water. This is shown in our next illustration (Fig. 13). When the piston A is raised, the water above it passes through delivery valve B to pipe C, at the same time water is passing from the suction pipe D through valve E to the bottom of the cylinder. When the piston again descends, the water below it is forced through delivery valve F into pipe C, while the top is again replenished by water entering through suction valve G from pipe D.

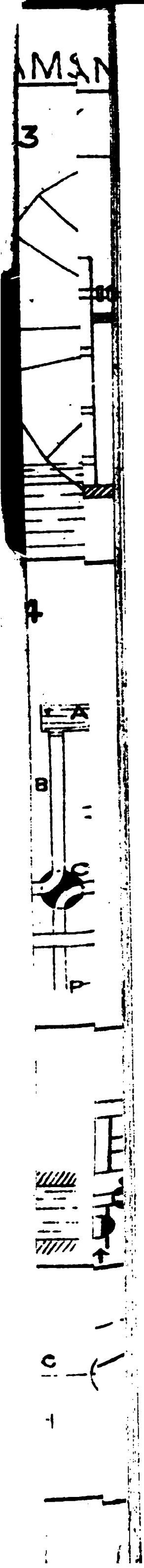
About 1739 a pressure engine or direct acting pump was introduced into some mines in France by Belidor, a noted French engineer. It depended for its action upon the same principle as Fludd's engine and the Roman buckets, and is shewn in Fig. 14. At A is a supply of water to be used as the motive power, passing down pipe B through the four-way cock C to the cylinder D, whose piston E is connected by the piston rod F to the piston G of a smaller cylinder H leading into a pipe I. With the four-way cock in the position shewn, the water acting through A B C D presses upon the large piston E and pushes it along to the end of the cylinder. The same movement being communicated to the piston H through the rod F, the water in I is forced through the delivery valve J into air-vessel K, whence it passes in a continuous stream by pipe L to an altitude M, as much greater than the altitude of A as the area of the piston D is greater than that of piston H, less the amount lost by friction. The lever of the four-way cock being actuated by a rod connected to the piston rod, the position is reversed at each end of the stroke. Upon the reversal of the four-way cock, as shewn in the side sketch N, the piston H is forced back by the pressure of the column of water in B, acting through

the pipe O, which takes the place of a suction pipe, and the water in cylinder D passes out through the waste pipe P.

In 1765 William Westgarth designed and erected in the North of England several pumping engines of the same description, but with vertical pressure and pump cylinders connected by means of a beam, somewhat similar to the steam engine of Newcomen. The first of these was fixed at Sir Walter Blacket's lead mines in the county of Northumberland. Upon the introduction of Mr. Westgarth's invention to the Society of Arts by Mr. Smeaton, a premium of fifty guineas was awarded; and upon the recommendation of the same gentleman, who was greatly interested in this machine, it was adopted as a prime mover by substituting a crank and fly-wheel for the pump.

This is shown in Fig. 15, A is the water supply, conducted by pipe B through an air-vessel C, to reduce the shock which would otherwise be caused at each stroke of the engine. At D is a plug-cock, worked by an eccentric E on the crank shaft. Through D the water passes to valve cylinder F, fitted with piston valves G and H, and now through the lower passage into cylinder I, pressing against piston J, and moving it upwards with the piston rod K, valve lever L, and beam M, depressing the connecting rod N and turning the crank O, causing the fly-wheel P to revolve. Upon the piston J reaching the top of its stroke, the piston valves G and H have been raised by their rod, so that the upper passage is now opened to the supply, and the lower one closed to the supply but opened to the exhaust Q, through which the water, having done its work in the bottom of the cylinder, passes away to the drain. The water from the top of the cylinder is similarly exhausted while the piston is moving upwards. In 1799 John Luddock obtained a patent for continuing the waste pipe downwards for a depth of about 35 feet, in order to obtain a vacuum on the side of the piston, opposite the pressure, and so make it equivalent to a condensing engine.

In 1772 Mr. Whitehurst, a watch-maker of Derby, made a



machine for raising water, now known as the Hydraulic Ram, the principle of which is shown in Fig. 16. A is the supply, B is a pipe laid with a fall towards the air-vessel C, which the water reaches through valve D, and from whence it passes by pipe E to the elevated reservoir F. The action of the machine is as follows:— As soon as the tap G is opened the water flows along B with a velocity depending upon its inclination, and upon closing the tap the water is unable at once to arrest its progress, the consequence being that a portion of it runs up through valve D into the air-vessel C and compresses the air, which compression re-acts upon the water and forces it up pipe E to reservoir F. Mr. Whitehurst's idea was to take the kitchen supply from tap G, and as this would be opened and closed many times in the day, he considered that enough water for use on the upper floors would be forced up by its own momentum; but as this machine was not self-acting, its practical value was not perceived until a French paper-maker, Montgolfier, of fire-balloon celebrity, added in 1796 a balanced valve in place of tap marked G, arranged as shown in the side sketch H. This valve has a weight pressing on it to keep it open, but as soon as the water attains a certain velocity, it pushes up the valve, which closes with a snap, and the arrested energy of the water causes a portion of it to enter the air-vessel. Immediately, however, that the surplus energy is consumed, the weighted valve again drops open, allowing the water to commence another rush. Numbers of these machines, with minor modifications, are in use at the present day, mostly for supplying gentlemen's country mansions, and the invention is often referred to as one of the neatest on record.

As we approach the nineteenth century, we leave behind us the multitudinous devices by which water was made to raise its own substance, and the direct application of water wheels or turbines to work of other descriptions, and enter upon an entirely new phase, in which the hydraulic press, invented by Joseph Bramah

in 1802, stands out to all posterity as the leading principle of modern hydraulic machinery. This inventor even went so far as to suggest its application to cranes and other machinery in the docks of Dublin and elsewhere, engaging to erect a steam engine in any part of Dublin, and convey the power to the machines by means of pipes. But docks were mere babies in those days; the necessity for such machines was not felt, nor was an opportunity for their introduction available. The grandest part of the scheme, therefore, slumbered for many years, until the re-invention of the idea, and the opportunity for carrying it out happening about the same time, it made those rapid strides which have rendered " hydraulic machinery " a household term.

The press of Bramah, patented in 1796, is shewn in its simplest form in our next diagram (Fig. 17). It consists of a small plunger pump, after Moreland's pattern, worked by a handle, the water being conveyed by a pipe to a cylinder in which works a large plunger. Upon the top of the large plunger is a table, on which may be placed the goods requiring to be raised. When the goods are removed, say at an upper floor, the plunger is lowered by opening the tap beneath the cylinder, allowing the water to pass out into a cistern, from whence it will be taken again by the pump at the next time of lifting. If the press is required for exerting pressure, as in the operation of baling wool, then another table is supported at a fixed distance above the large cylinder, the bale being squeezed between the two tables. Although Bramah specifically designated his invention as applicable to cranes, it is doubtful whether he ever foresaw the practical difficulties to be overcome in enabling these cranes to compete successfully with others, and we must not too hastily award to him undue credit. Even his press was suggested by Pascal 150 years before, but Bramah first brought it into practical use. It had a somewhat extended application for packing presses, oil presses, and testing machines, and its efficiency was much increased by Benjamin Hick's invention of a self-tightening packing, having little friction, viz., the leather collar

used in the present day, and commonly known as a cupped leather. This is shown in the next figure (18), where A is the ram or plunger, B the cylinder, and C C the cupped leather, placed in a groove in the contracted part of the cylinder and encircling the ram. It will be seen that the water has access to the inside of the bent leather, and by its pressure forces the sides outwards, preventing the escape of any water, and at the same time allowing the ram to move with very little friction.

In the *London Chronicle* for February 1803 appeared a description of a new engine, invented by a gentleman named Harriott, for raising and lowering weights and for other purposes, worked by a column of water, the principle of the syphon being combined with the direct pressure of a stream or column of water. The description further states that this engine raises or lowers goods with thrice the velocity usually produced by manual power, being worked without other exertion than that of a boy turning a cock to the stop marks on an index.

Upon the advent of Watt's steam engine, and owing to the sensation it created in the mechanical world, the peculiar advantages of water pressure engines were lost sight of for some time, but in 1803 Trevethick erected one at the Alport Mines, Derbyshire, where it was in use for many years. Mr Glyn, to whom I have before referred, designed another water pressure engine for the same place; it was fixed in 1842, and was the largest of the kind up to that time. Some idea of its magnitude may be formed when I state that the cylinder was 50 inches in diameter and the length of stroke 10 feet, upwards of 4,000 gallons of water being raised to a height of 136 feet every minute. Among the numerous advantages of hydraulic machinery is the small amount of attention it requires compared with other machinery. On one occasion when Mr. Glyn enquired as to the performance of this engine, after it had worked for six years without intermission, the answer was, that it had been going constantly for the last 17 weeks, but *nobody had seen it* during the time.

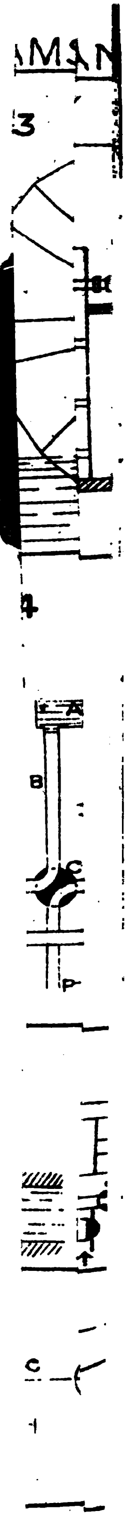
In 1810 Matthew Murray, of Leeds, used a hydraulic cylinder suspended from three legs as a direct acting crane for lifting heavy boilers, the water pressure being obtained from a tank at an elevation of 60 feet.

In 1844 Mr. Phipps constructed a direct acting hydraulic wagon hoist, with 10 inch ram and 20 feet stroke, on the Great Eastern Railway. The principle was precisely that of Bramah's press, and the pump was worked by a steam engine.

About the same time the Butterley Company constructed two lifts at Osmaston Manor, near Derby, the larger of which consisted of a cast iron cylinder sunk in the ground, put together in lengths making about 46 feet in all, and truly bored to an internal diameter of 11 inches, in which worked a piston made water-tight with a leather collar. To the top of the piston rod was attached a platform railed round, upon which passengers were carried. These lifts were worked from a reservoir about 90 feet above the basement level.

In 1849 a notable use was made of Bramah's press by Robert Stephenson and William Fairbairn, in lifting the tubular girders of the Conway and Britannia bridges. In the latter bridge these tubes weighed about 1,800 tons each, and were lifted in successive operations to a total height of 100 feet.

We now arrive at the most interesting period of the development of hydraulic machinery; hitherto we have seen only a very gradual advance. Many good ideas took practical form during the first half of this century, only to remain as isolated examples of the capabilities of water, either for the generation or transmission of power; but now we find a sudden expansion of the principle, branching out in all directions with such profusion, that we feel compelled to admit that, wherever mechanical power is required, water pressure can be made the efficient agent. All this is due to the skill and energy of a single individual, so well known to you in connection with hydraulic machinery that I scarcely need to name him to recall to your recollection Sir William George Armstrong.



I had the good fortune to be associated with the firm of Sir William Armstrong & Co. for twelve years in superintending the erection of their machinery in London, and it is with much pleasure I enter upon this portion of my subject.

To appreciate the credit due to Sir William Armstrong, we must go back a few years, until in 1836 we reach the origin of his inventions. Travelling through the deep valleys of the Craven district of Yorkshire, his attention was attracted by "various mountain rills, which, descending the steep slopes of the hills, expended their energy in the production of streaks of foam, thereby adding to the beauty of the landscape, but fulfilling no purpose of utility. In one particular instance he observed an overshot water-wheel, which employed about 20 feet of the fall of one of those small streams, while several hundred feet of the entire descent remained unproductive. It naturally occured to him that if the stream were conducted in a pipe from the highest available point and the pressure of the contained column were to act mechanically at the bottom, the power afforded might be increased in proportion to the greater fall brought into operation."

Now, in tracing out the schemes by which this idea was perfected and extended, we must remember that although fond of mechanical pursuits from a very early age, Sir William Armstrong was not at that time an engineer, but in practice as a solicitor, to which profession he had been brought up, and he has stated that he was then wholly unacquainted with the applications of water power that had been previously made. His first device was a new form of water-wheel, to be worked by one of these mountain rills brought down to it in a pipe. The principle will be easily understood from the next figure (19). A is the pipe conveying the water to work the wheel B. This wheel has a thin flat rim with four circular holes through it, marked C. In these holes are fitted discs, pivoted through their centres so that they can be put flush with the rim, or made to project on both sides at right angles to it; the side sketch D shews one partly open. The pipe A encircling

the lower part of the wheel is split along the top to allow the wheel to work in it. The discs are moved by external cams, so arranged that as the wheel revolves they enter the pipe while folded in flush with the rim, but immediately they have entered, they open out, so as to fill the pipe like a piston, receiving the pressure of the water and communicating power to the wheel. A model made in 1839 realised a high efficiency, but like many other inventors before him, Sir William found nobody to adopt his machine.

In 1840, in a letter to the *Mechanic's Magazine*, he described many of the applications and advantages of a hydraulic system, and pointed out that when water is lifted by a pumping engine it becomes the recipient of the power exerted in raising it, and if the same water be used as a motive power, in its descent to its original level, it renders back the power conferred upon it by the engine, and thus becomes the medium through which the power of the pumping engine may be transmitted to a distance and distributed in large or small quantities as occasion may require. Also that a small engine pumping *continuously* into an elevated reservoir is able to supply many powerful machines working *intermittently*.

As soon as the fitness of hydraulic power to the operations of cranage became apparent, he saw that it would be better to effect the process of lifting by the single stroke of a piston, obtaining the necessary range of lift by some method of multiplying the motion. Eventually he decided upon the plan now adopted, of passing the lifting chain over sheaves arranged in the inverted order of pulley tackle. This arrangement may be best explained by taking a somewhat later form, and describing it as a Bramah press put between the upper and lower blocks of a pulley tackle, the press exerting great power in forcing the blocks apart through a short distance, and causing the loose end of the chain to move rapidly with a comparatively higher load through a great distance. A crane was then designed upon this principle, with the addition of another cylinder to swing it round, the piston of the latter cylinder

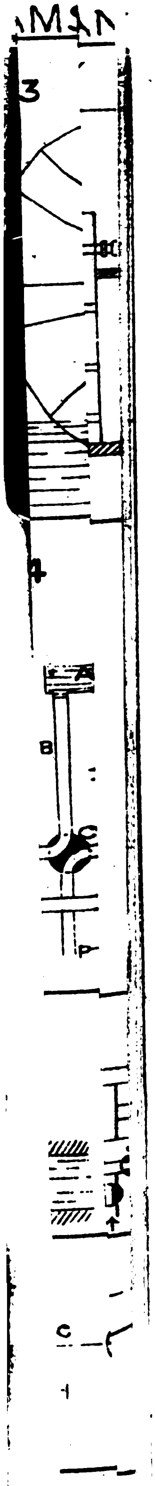
being attached to a rack working into a circle of teeth at the base of the crane. Suitable valves were arranged to admit and release the water, and a small but important detail that many a less careful inventor might have overlooked, was also added. This was a series of relief valves to prevent damage to the cylinders if the motion of the crane should be suddenly arrested. The principle of these is shewn in Fig. 20, where A is the supply pipe from which the water passes through the regulating valve B to the cylinder C, and presses upon the piston D, escaping by valve E when the load is being lowered. If the valve E should be suddenly closed while the load is lowering, the momentum of the load and moving parts will be communicated to the water, which, seeking a way of escape, will force up the relief valve F and a small quantity will pass back through pipe G to supply pipe A. A working model of the crane thus designed was made, and was found to answer exceedingly well, but still no one came forward to adopt it, although it had been made known to the public.

At last an opportunity offered, and in 1846 one was fixed on the Newcastle Quay, the water pressure being obtained from the town water pipes. The principles were such as I have described, but three lifting cylinders were applied in order that the power might be varied to suit the load, the cylinders being used separately or collectively as required. This crane excited much curiosity, and well it might, for it was not only the first practical application of water pressure to ordinary cranage, but it worked admirably, every movement being entirely under control. Engineers came from all parts to see it, and among them an eccentric old gentleman, Mr. Jesse Hartley, engineer of the Liverpool Docks. It was not at work when he arrived, but "Hydraulic Jack" was there, the man who looked after it, and Mr. Hartley entered into a conversation with him. The man, who had become quite dexterous in managing the crane, gave an account of its wonderful capabilities and his own too, until Mr. Hartley appearing incredulous, the man was put on his mettle, and rising to the occasion, offered to drop a hogshead

of sugar from the highest point of the crane and pick it up before it reached the ground. This was eventually performed to the satisfaction of the visitor, but, like a true north-countrymen, the canny Northumbrian prefaced his operations with the remark, "An' what 'll ye stan' if I show ye?" The result of this episode was an order for some cranes for the Albert Dock, Liverpool, soon followed by orders from other engineers, and the new system of machinery was fairly launched on the world.

Hydraulic cranes were first used for railway station purposes in 1848, at the Trafalgar goods station, Newcastle-on-Tyne, on what is now the North Eastern Railway. Up to the beginning of 1849, all the cranes which had been erected derived their power from the town reservoirs, but now two cases arose in which the town supply did not afford sufficient pressure, and the expense of constructing special elevated reservoirs would have been too great. It was therefore decided to adopt steam engines for giving pressure to the water by means of a plunger pump at each end of the cylinder, the piston rod being continued through both ends to the steam cylinder to form the plungers acting in the pumps. To equalize the pressure of the water supplied to the cranes, an air-vessel was connected to the supply pipe near the engine as shewn in Fig. 21. This expedient answered fairly well, and is even now used in some cases where much weight is undesirable, but there are several inherent defects in an air-vessel for this purpose.

In 1849 hydraulic machinery was put in hand for the Great Grimsby Docks, were the pressure was obtained by building a tower 200 feet high, to carry a reservoir into which the engine pumped. This was a great improvement over the town supply system, because the fluctuation in the pressure from a variable draught was avoided. Here the water-power was used for working cranes, for opening and closing the dock gates, and for working the sluices. There were two parallel entrance locks, 70 feet and 45 feet in width, and three pairs of gates in each, the twelve leaves being all worked by three cylinders on the system shown in the



next diagram (Fig. 22). A is a cylinder fitted with a piston; the piston rod continued through each end of the cylinder carries at its extremities sheaves BB, round which a chain is passed, as seen at C; one end of the chain is fixed and the other takes hold of another sheave D, carrying a similar chain E; by this arrangement, which is similar at each end of the cylinder, the travel of the piston is multiplied four-fold either way. The end of chain E is connected to a flat-linked chain F, which is conveyed along the whole line of gate crabs, and is arranged to gear with a cog-wheel G running loose upon a shaft, but able to clutch the drum of any one gate machine which may be required to act. The sluices were worked by a simple cylinder and piston, as in Fig. 23, the water being admitted below or above the piston, according as the sluice paddle was required to open or close.

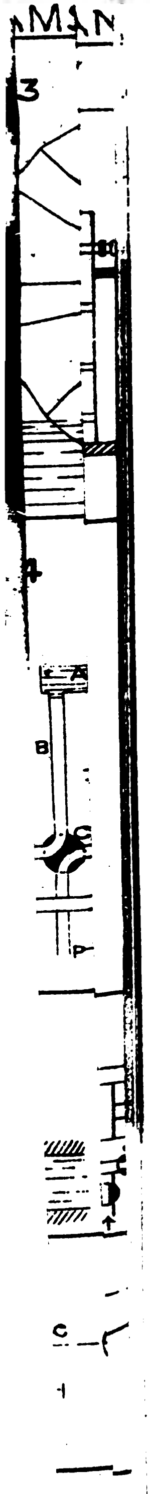
In the same year of 1849 some water-pressure engines of a more compact form than any previously adopted were designed by Sir William Armstrong, and fixed in the mines at Allenheads; each engine was composed of two cylinders, placed at an angle of 45° to the bed-plate, and at right angles to each other. They were connected to the same crank-pin, and worked by balanced cylindrical valves, having relief valves similar to the crane machinery.

In the year 1850 hydraulic machinery was decided upon for the New Holland Station of the Manchester, Sheffield, and Lincolnshire Railway, In this case there was no possibility of obtaining an elevated reservoir; the ground was of such a nature that no foundation for a tower could be obtained, the air vessels previously used were not altogether satisfactory, and Sir William was led to devise that most valuable piece of apparatus, now universally used with all kinds of hydraulic machinery, the "accumulator," introduced in 1851, and shown in our next diagram (Fig. 24). It consists of a vertical cylinder A, in which works a ram or plunger B carrying a cross-head C, supporting a weight or weights D D, usually in the form of an annular casing carrying ballast. When the engine starts pumping, the water is forced into the cylinder of

the accumulator, raising the ram and with it the hanging load, but immediately any water is required at any of the machines the ram lowers and forces the water through the supply pipes with a pressure proportionate to the load hanging on the cross-head. The accumulator thus answers all the purposes of an elevated tank without its expense, and enables a much greater pressure to be used. Previously 90 lbs. per square inch was the maximum, now 600 lbs. was used, equal to a head of 1,500 feet. This increase of the pressure enabled smaller pipes and cylinders to do the same work, and from the adoption of the accumulator we may date the establishment of hydraulic machinery as a mechanical necessity and a national industry.

In this, as in many previous inventions, a trifling addition effected great results; a chain from the accumulator, shown in Fig. 25, was connected to a weighted lever, attached to a throttle valve in the steam pipe supplying the engine, so that as the accumulator rose the lever fell and closed the valve, opening it again as the accumulator lowered. The working of the engine was thus automatically regulated, the power being expended only when required by the working of the machines. The increased pressure caused some difficulty at first in connection with the pipe joints, but that was soon overcome by inserting a ring of gutta percha cord in each joint, and squeezing it up as in Fig. 26, where one side of a pipe is shewn.

The first hydraulic machinery fixed in London by Sir William Armstrong was in 1851, at the Poplar Dock Station of what is now the North London Railway. It was at that time generally called the Collier Basin of the West India Docks, and belonged to the Northumberland and Durham Coal Company, to whom my father was engineer and manager. This machinery was for unloading coals from screw colliers by means of what are called raking jib hoists; the arrangement is shewn in the next diagram (Fig. 27), where A is the raking jib hinged at its lower end to a wooden structure containing the machinery, and raised or lowered



by a cylinder B, whose chain C is attached to the upper end, so that the coal tub D raised or lowered by cylinder G may be made to plumb the hatchway of the ship E or the railway truck F. You will observe in this figure the now usual form of hydraulic cylinder and ram, there being no piston, and the chain being folded round one set of sheaves on the ram end, and another set on the cylinder end, being equally efficient and more compact than the system adopted with the Newcastle crane and the Grimsby gate machines. In this way the stroke has been multiplied in some instances as much as twelve times, with of course a proportionate reduction in the weight lifted.

At the Poplar Dock the water pressure was obtained by a steam engine and accumulator as before described. Owing to the trade of this place having altered, three of these hoists, for landing sea-borne coal, have recently been replaced by some excellent tipping machines for shipping inland coal.

In the year 1851 hydraulic machinery was also being applied to a variety of purposes at the Paddington Goods Station of the Great Western Railway. It was made to work cranes, turntables, traversers, capstans, hoists,and printing machines.

It would take too long to describe to you the numerous modifications which have been made from time to time in the details of the Armstrong system, and I must therefore select a few of the more important points in illustration of the general subject. The steam engines had at first a simple plunger pump at each end of the cylinder; then with a view to greater compactness the pump behind the cylinder was discontinued, and the other one made double acting upon the combined bucket and plunger system as used in common lifting pumps, and finally a neat modification was made by Henry Thompson, the Elswick foreman, which has since remained the standard pattern. This is shewn in the next illustration (Fig. 28.) A is the pump, B the piston, and C the piston rod or pump ram as it is generally called, D a passage leading to the suction valve E and suction pipe F, G is the delivery valve, H a check delivery valve (a

later addition), and I the delivery pipe to accumulator. The action is as follows:—On the piston making its out-stroke, that is, in the direction of the arrow, the suction end of the pump is filled with water through pipes D, F and valve E, and on the in-stroke this water is forced out again through pipe D and delivery valve G, until it reaches the branch pipe J, where it divides, half passing through valve H and pipe I to accumulator, and the other half going up pipe J to delivery end of cylinder, filling the annular space round the ram or piston rod, which is just equal in area to half the piston area. On the next out-stroke of the piston the water in front of it is forced through J, H and I to accumulator, making the pump double acting and all parts easy of access.

Bridges worked by hydraulic power have been improved in detail, but the general principle remains unaltered. Draw bridges are lifted off the resting blocks by two presses carrying rollers on the rams, and then hauled by hydraulic cylinders. Swing bridges of ordinary size, of which a large number have been made, are lifted by a centre press, and turned by a pair of hauling cylinders.

Gate machines were first worked as I have described at the Grimsby Dock; then cylinders with plain rams were used, the chain passing over sheaves at each end, and a separate cylinder applied to each gate, as at the West India Docks. Afterwards a water-pressure engine was adopted, giving motion to shafting, to which each gate crab might be connected by means of a clutch, as at Swansea; and then a separate engine to each crab was used, and this was the ordinary type for many years; but recently Mr. Westmacott the talented partner of Sir William Armstrong, has devised a plan of using a single chain for opening and closing each gate, made fast at its extremities to the masonry on either side of the lock, movement of the gate being obtained by placing the engine in the gate, gripping the chain by means of a cupped drum, and so walking along it in either direction. This arrangement effects a great saving in foundation work, and is likely to be largely adopted. Where first cost is no object, plain cylinders and rams may be adhered to, as the labour for maintenance is almost nil.

The machinery of the cranes also underwent various improvements. The original Newcastle crane had three lifting cylinders, fitted with pistons, arranged so that either one, two or three might act upon the cross-head to which the sheaves were connected. In subsequent cases, as at the West India Docks, three cylinders with plain rams were used, the cylinders being placed vertically, and the rams returning into the cylinders by their own weight on the release of the water by the exhaust valve. Afterwards a double power was obtained by one cylinder, having a differential piston and ram, similar to the steam engines. This arrangement, as adopted at Woolwich Arsenal and elsewhere, is shewn in Fig. 29, the valves being slightly altered to shew the principle more clearly. A is the pressure valve, B the exhaust valve, and C an independent valve; in the position shewn, the water is passing through A to both ends of the cylinder, but although the pressure of the water is equal in each end, the surfaces upon which it is acting are unequal. On one side we have the full area of the piston, and on the other side we have less by the area of the ram; the consequence of this is that the total pressure on the piston side overbalances the total on the other side, and forces the piston along the cylinder, the water on the ram side passing round to the piston side; this is the lower power. The higher power is obtained by closing valve C and opening valve B, then the full pressure of the water acts on the piston, without deduction for counter-pressure, the ram end being open to exhaust through valve B. The lowering of the load is effected by exhausting both ends of the cylinder, A being closed while B and C are both open.

The next great improvement in the cranes was their adaptation to the purposes of weighing coal while discharging it from the hold of a vessel. This was effected by having a separate lever or beam carrying the jib-head sheave, as in Fig. 30, and supported on a knife edge A fixed on the jib; the small weights B on the long end of the lever balancing the heavy tub of coals C at the short end. Twenty of these cranes, forming part of a large plant of machinery under my present charge, weigh and deliver about two million tons of coal in the course

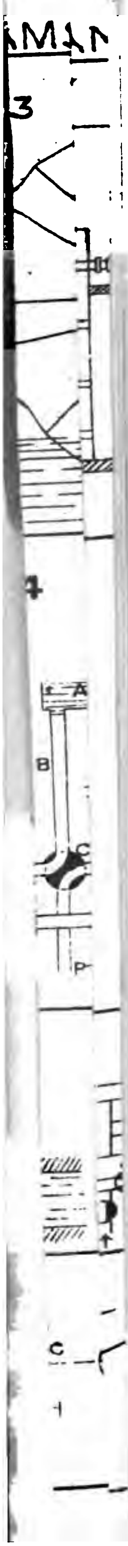
of a year, the maximum work per hour being 65 tons lifted 30 to 40 feet for each crane. These cranes, belonging to Messrs. Wm. Cory & Son, have been frequently alluded to in various published records of hydraulic machinery, as forming an excellent example of what can be done in the way of discharging coal rapidly and economically, the cost so far as the machinery is concerned being only about one penny per ton, lifted 40 feet, swung through half a circle, weighed and delivered.

Another great improvement where the cranes were required for use on a railway platform, was the placing of the lifting cylinder between the cheeks of the pillar, making the crane self-contained, that is, requiring no foundation beyond what the foot-step stands upon, as at the Nine Elms Goods Station of the London and South Western Railway. Then we have the lifting-cylinders themselves made to do duty as crane-pillars, as at the Victoria Docks Depot of the Midland Railway. Then we find the cranes made moveable, so that they may be shifted to any required position, still being connected with the water-pressure main, as at the London Docks; and lastly we have everything cleared away from below, and the crane, with a horizontal jib and no pillar, placed up in the roof, as at the Farringdon Goods Station of the Great Northern Railway.

In effecting the swinging of crane-jibs, the rack arrangement of the Newcastle crane was soon improved upon by using a pair of small cylinders, placed one on each side of a grooved drum at the base of the pillar to which the turning-chains were attached.

The movement of the valves in the Newcastle crane was obtained by a crank-handle turning a screw to points marked on an index-plate; subsequently, by means of levers, the simple movement of a handle forward or backward accomplished the same result.

The application of a simple hydraulic crane to coke stages, in connection with a hopper; from which the locomotives may take the coke direct, has not received the attention it deserves; various forms have been proposed, but I am not aware of a satisfactory solution having been obtained. The arrangement must be compact, light, cheap,



and applicable to cases where only a low water pressure is obtainable.

Many plans have been tried for adjusting the power of a crane to the load to be lifted, but the cost of the water is so slight that any saving in this respect is generally more than counterbalanced by the increased cost of the machinery, except in large cranes. I devised a plan some six years ago of adapting an injector nozzle to the supply pipe of any hydraulic machines, in such a way that when a light load was to be dealt with, the energy of a portion of the water would be expended in drawing in by an induced current some of the exhaust water and by so much reducing the amount of pressure-water required. This scheme went no further than preliminary sketches, which I have by me now, but the idea has been recently brought forward again quite independently by my friend Mr. Martindale, and may, possibly, some day be put into practice.

The types of cranes that I have mentioned form only a small sample of the varieties constructed on the Armstrong system; the individual examples have varied so much that it would be impossible for me to describe them to you in one evening. Almost every possible form has been used according to the varying circumstances of each case, and notwithstanding the vast mass of machinery which has been turned out from the Elswick Works, no firm has had fewer mistakes to rectify. The credit for this is largely due to that most careful of men, the late Chief Draughtsman, George Hutchinson.

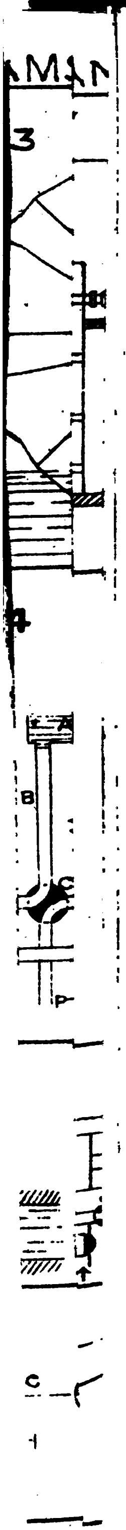
Of the water-pressure engines, the first had two fixed cylinders with connecting rods, as at Allenheads; then we find three cylinders, equally divided round a circle, the third one being vertical, as at Paddington, for working the printing presses. The application to hauling purposes then made horizontal cylinders desirable, as in the capstans at Paddington and Haydon Square, the valves of which were mitred spindles worked by weighted levers, moved by cams on the crank shaft. After this we have a great improvement in the cylinders being made oscillating with plain rams, the valves being slides worked by links attached to the cylinders; and afterwards the same type, but with the valves worked by eccentrics on the cylinder trunnions, and

for general purposes this pattern has never been improved upon in any of the numerous variations which have since appeared. There have, however, been other forms suitable to special cases, where lightness and economy in first cost have been an object. In the earlier examples of these other forms the engine has two cylinders, made double-acting by using combined pistons and rams with trunnion valves; afterwards by the addition of a third cylinder and an improved valve arrangement, a second and third power were obtained by means of differential pressures, in the same way as I showed you in the case of the double-powered crane (Fig. 29). The pattern now adopted for railway capstan purposes consists of a pair of oscillating cylinders with trunnion valves, the piston rods attached to one crank fixed on the bottom of the vertical shaft passing through the capstan head, the whole of the gearing being attached to the bed-plate, and moveable upon trunnions or hinges, through which the water is conveyed to and from the cylinders.

The first wagon hoists consisted of cradles lifted by chains, as at Paddington Station, afterwards the lifting cylinder was placed in a pit under the platform of the hoist, the weight of the platform, &c., being balanced by counter-weights hung by a chain carried over sheaves and attached to the platform, as at the Blackfriars Station of the London, Chatham and Dover Railway. Then the balance weight and chain were dispensed with, and a small constant-pressure cylinder put alongside the lifting cylinder, to take the weight of the platform without consuming any water, as at Broad Street Goods Station of the London and North Western Railway.

When a railway platform is required to be sometimes continuous for traffic over it, and sometimes broken for traffic through it, a movable piece is inserted of the width and length required. At Paddington this piece is hauled under the fixed portion by hydraulic cylinders; at the Midland Railway, St. Pancras, it is lowered down into a recess at rail level and worked by a very simple arrangement of hydraulic press and knuckle gear.

Trucks often require to be transferred from one line to another



this is most conveniently effected by means of the hydraulic traversers, which are simply low frames upon which the trucks are run and then hauled on transverse rails across the metals to any particular line where they may be required. The hauling is in some cases done by special cylinders and in others by ordinary capstans; both methods are in operation at St. Pancras.

Where there is an upper floor to a station, jigger hoists are much used; these consist of a crane cylinder with the chain led over conveyance sheaves to a trapway giving access to the lower floors. This is a very economical and rapid method of dealing with light goods. Heavier goods are more often raised in small cradle hoists, fitted with stops to hold them at any floor.

Direct acting pumps, worked by the ordinary accumulator pressure of 700 lbs. to the square inch, have been used for some years for supplying stations with water; examples of this method are found at St. Pancras and Broad Street.

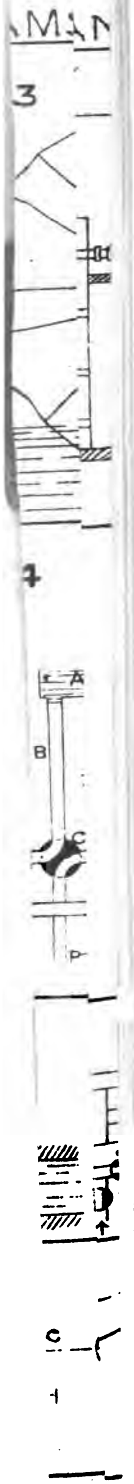
Although hydraulic machinery, in the form of cranes or hoists, has established itself as an indispensable adjunct to all buildings of any magnitude where merchandise is dealt with, it is astonishing how little its details are known to architects. A few years ago, an architect who had carried out several engineering works, and was moreover a Fellow of the Royal Institute of British Architects, built a large waterside warehouse and quay, for which he ordered the requisite hydraulic machinery. While this was being fixed, he observed the apparently complicated valve arrangement of a multiple-powered 10-ton crane, and privately gave me his firm opinion that it was all humbug put in to increase the cost, and that the pipes ought to have been laid straight away to the crane-jib. I did not appreciate the force of his remarks until some time afterwards, when he informed me that he thought the cranes were worked by chains from the engine led through the pipes, which we had first put in.

The application of hydraulic power to band machinery, to coal shipping hoists, to winding engines, and many other purposes, might claim our notice, but I must now bring to a close this rapid survey of

the Armstrong system, and regret that time will not permit me to enlarge upon it here. It may, however, interest some of you to know that I have arranged to deliver a course of ten lectures, at the City of London College, on the "Practical Designing of Hydraulic Machinery."

We must remember that we are dealing to-night not with one system, but with the general subject, and I must bring to your notice a few other prominent names. Foremost among them is that of Ralph Hart Tweddell. What Sir William Armstrong has done for outdoor machinery Mr. Tweddell is doing for workshop and yard tools, and of these the portable rivetter is the most noticeable. It consists of a small hydraulic press, slung from a crane-jib in such a way that it may be moved about to any part of a boiler or other rivetted structure without interfering with the pipe connections. In facility of handling, rapidity of work, and accuracy of execution, its performances are unrivalled. An illustration of this is shown in Fig. 31. A B are two levers working like the claws of a lobster, bearing against each other at one end, and holding dies for forming the rivet heads at the other. They are shewn in the act of rivetting a girder. C is a cylinder connected to the upper lever A and D is a ram connected to the lower lever B; E is an inner ram fixed to cylinder C, with a constant pressure from the accumulator passing into it through F, and thus into the annular space G. H is the pressure pipe, admitting water to the annular space I, and J is the exhaust pipe for removing the water when done with. Now it will be seen that the pressure in I is pushing D up and C down; this movement is communicated to the levers A B, and so the rivet is closed. Then, on opening the exhaust valve, the pressure in G comes into action, lifting C and A, and lowering B and D, so that the apparatus may be moved to the next rivet.

This ingenious system is also applied to punching and shearing machines, slotting machines and other heavy tools, and has been largely adopted on the Continent. I should have been glad to describe these applications but they are worth an evening to themselves, and perhaps Mr. Tweddell may be induced to give you a lecture upon them illustrated by some of his beautiful models.



A few of the hydraulic appliances of Mr. Andrew Betts Brown call for our attention; among these is the steam accumulator, in which the dead load is replaced by steam pressure acting upon a large piston, which is attached to the ordinary accumulator ram. This permits the accumulator to be placed horizontally when more convenient, and also allows of a simple adjustment of the pressure to the loads lifted, when applied to a small plant of machinery; but for ordinary work the dead load accumulator in one or other of its various forms is unsurpassed. This gentleman has also applied hydraulic reversing gear to the engines of steamships, and similar mechanism to control the movements of the rudder. In connection with lifting gear for discharging cargo, he has brought out an ingenious arrangement by which the throw of the crank in a hydraulic winch is altered, so that, as the throw is increased or reduced so is the stroke of the rams, and the varying leverage thus adapts the engine to varying loads with corresponding economy in consumption of water.

Messrs. Tannett and Walker have made some good applications of hydraulic power to Bessemer plant, and other firms are also repeating well established examples. Many are working in the same direction, and there is ample scope for all.

We have now seen the principal modifications which have been produced through the course of ages. Many important machines have escaped our notice, and numberless happy contrivances in the details, but time fails us.

Upon reviewing our subject, we find that hydraulic machinery has passed its long infancy, it has outgrown the rapid development of its youth, and is just entering into the prime of its manhood. There are many industries still awaiting its silent force; the mountain rills and the ocean tides alike call for useful application of their power, and bold indeed would be the man who would venture to say that the future of hydraulic machinery would not be even greater than the past.

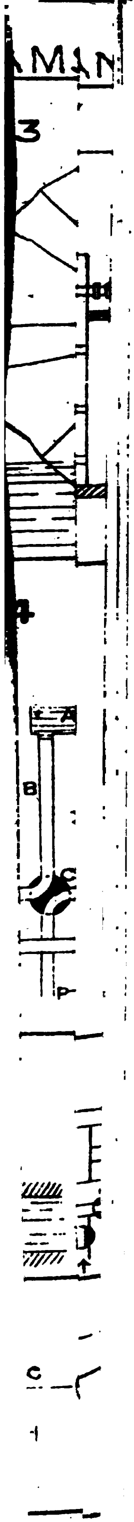
I am afraid that my long and disjointed lecture will have somewhat wearied you. Pressure of other business has prevented me from

devoting the time to its preparation that I should have wished, but I trust that I have been able to give you some idea of what is foreshadowed in the title, "Hydraulic Machinery—Past and Present."

At the close of the lecture THE PRESIDENT said it gave him great satisfaction to have been the means of introducing to the Association a practical paper of such value from his nephew, the lecturer, and if the Committee would allow him he would be happy to undertake the cost of printing and distributing a copy to each member. He remarked that for some years the coal hoists at Poplar were under his charge, but he might say he never heard of them, for they really required no repairs beyond the occasional grinding in of a valve, or putting on a new lifting-chain. Hydraulic machinery was characterised by immense force, with little wear and tear, owing to the slow movement of the working parts, while the multiplication of the speed by pullies made it answer all purposes. He would not detain them with any further remarks, as there were many members and gentlemen present who were more or less acquainted with hydraulic machinery, and he hoped they would have a good discussion, showing up the weak points, if there were any.

A discussion then ensued, in which several gentlemen took part. The following is a brief abstract :—

MR. JACKSON, District Locomotive Superintendent of the Midland Railway at Kentish Town, said that for many years he had had under his supervision a large quantity of hydraulic machinery, and found it superior to any other mode of dealing with heavy weights, either in lifting or hauling. He wished also to acknowledge the assitance he had derived from the lecturer in the personal interviews which his business had necessitated from time to time. With respect to the printing of the lecture, he did not think the Committee ought to allow the President to bear the expense; they could afford to pay



for it themselves, and he thought it was only right they should do so; at the same time he thanked the President for his very kind offer.

Mr. John Lee, having the immediate charge of the hydraulic machinery belonging to the Midland Railway in London, as foreman under Mr. Jackson, desired to corroborate all that Mr. Jackson had said.

Mr. Tweddell said he had heard many papers on hydraulic machinery, but none in which so much information was condensed into so small a space, or where such impartial justice had been meted out to inventors in all ages. We had here at one view all the principal inventions bearing upon the use of water power from the earliest times. When he heard of the variety of hydraulic machines put into use before the time of Sir William Armstrong, he began to fear that perhaps some of the ancients had also anticipated the portable rivetter, but he was glad to find they had not. He then described some of the schemes which had been proposed for a general high pressure system, by which wharfingers and others could have the water laid on to their premises for working cranes, &c., without the necessity for an independent steam engine at each place, and instanced the case of Hull, where the system has been satisfactorily working for some time.

Mr. Homfray, from the firm of Sir W. G. Armstrong & Co., acknowledged the compliments which had been paid to Sir William Armstrong by previous speakers, and mentioned some of the most recent applications of hydraulic power by that firm, among them the new swing bridge over the Tyne, of which he gave some particulars, and the new fire-extinguishing apparatus at the London Docks.

Mr. Garrett described a method adopted at some places for coaling the engines, where the trucks were run up an incline, and the coal thrown out into a hopper. He said it would be of great advantage to apply hydraulic power to the large engine turntables, to avoid the constantly recurring difficulty of "something wrong with the centre."

Mr. Manico, Chief Draughtsman in the Locomotive Department

of the North London Railway, said that three of the coal hoists at the Poplar Docks, which had been referred to as the first hydraulic machinery erected in London, were still at work unloading screw colliers, apparently as perfect as ever, and likely to last for many years longer. The hydraulic tipping machines for loading barges from trucks answered admirably, and effected a great saving on the former methods.

MR. THOMPSON, a Resident Engineer on the Great Northern Railway, said that the machinery at Farringdon Street Goods Station had been referred to, and he was happy to bear testimony to its efficiency, and also to the valuable information he had received from Mr. Adams at various times. This machinery was chiefly remarkable from the fact that the pumping engine for giving pressure to the water was situated some distance off, under the Smithfield Market, the water being conveyed along the railway to and from the engine-house by pipes laid in the ground. No difficulty was experienced in this arrangement, as they had an additional accumulator near the point where the heaviest work occurred, and he thought this might be adopted in other cases with advantage. He believed the cranes and machinery generally were the most perfect of their kind, and he should be happy to show them to any of the members.

MR. JOSEPH NEWTON, President of the London Association of Foremen Engineers and Draughtsmen, said he had been connected for many years with Associations like the one whose members were now present, and he found that where the members were willing to help themselves they would always find other people ready to assist. He understood that, although not a new society, it had only recently started the reading of papers, and he thought this was a step in the right direction. A benevolent society was all very well, but they wanted something more than charity to hold the members together, and he thought they could do no better than continue that new sphere which had been so well begun. He had listened with much pleasure to the lecture which had been given that evening; and with the aid of the diagrams, which had been so lucidly described, he

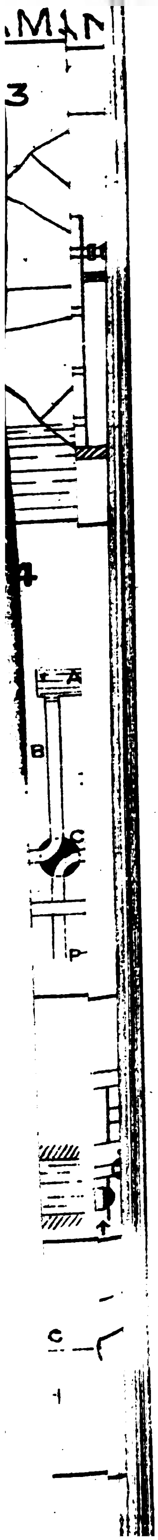
thought no one present could have failed to learn a great deal about hydraulic machinery.

Mr. Duckham, Engineer of the Millwall Docks, said he had recently had occasion to put down more pumping power, and he had gone back to the oldest form of Sir William Armstrong's engine, in which plain plunger pumps were used, one at each end of the steam cylinder. This of course took up a great deal of room, but as they had plenty of space he preferred the simpler pattern. He had also replaced the gate machines with the old pattern of cylinder and ram first used in London, as he found the cost and trouble of maintenance were much greater with the new pattern than with the old.

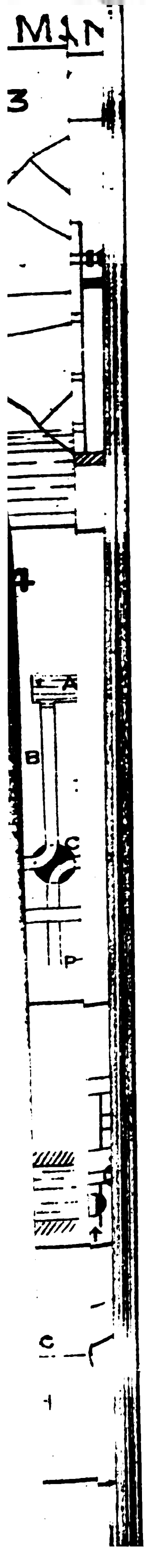
Mr. Pischon said it was rather remarkable that the earliest application of water-power, illustrated in the diagrams, was for the purpose of religious deception, while the same motive had prompted its use in the latest instance that had come under his notice. He received from Spain, a few days ago, a newspaper containing an account of the way in which an image of the Virgin was made to weep in sympathy with its worshippers, by the turning of a tap by which water was admitted through a small pipe concealed in the image and terminating at the eyes, the tears being turned on or off, as occasion might require. He also called attention to the fact that in Switzerland perambulating hydraulic machines were very common. A man would travel about with his machinery from house to house, connecting to stand pipes on the water mains, wherever required, and sawing up wood or doing other useful work for the inhabitants.

After a few remarks from other gentlemen,

Mr. Henry Adams, in reply, said that he had not attempted to illustrate modern hydraulic machinery beyond its first principles, as it would have involved considerable labour, and there were already numerous published diagrams in the minutes of proceedings of the Institutions of Civil and Mechanical Engineers. He had confined his references in the modern portion principally to railway depôts



in London, from which there were so many representatives present. With regard to swing bridges, there were several large bridges in existence worked by hydraulic power; the reference which had been made in the lecture to swing bridges did not exclude these, but described specially the action of the smaller ones. At the Millwall Docks we had a unique case of hydraulic machinery of a modern pattern being removed for the application of an older form. He did not doubt that there would be less expenditure for maintenance after this alteration, but the first cost in machinery and foundations would be far in excess. Many cases happened in which makers of hydraulic machinery were compelled, by considerations of first cost, to design machinery which required more careful supervision; this may have been one, but inasmuch as a very large number of similar machines to these discarded ones were at the present moment in use elsewhere, and no special difficulty was found, he thought the machinery ought not to get all the blame. With regard to the steam engines, it took only twenty minutes to change a pump leather, and the slip varied from 3 to 5 per cent., so that it was doubtful economy to go back to the cumbrous single-acting engine. The application of accumulator pressure to fire-extinguishing purposes was made in 1854, at the West India Docks, by means of a reducing valve. Good use has been made of this at various times, but the latest development alluded to by Mr. Homfray is an undoubted improvement, worth the attention of all users of water under an accumulator pressure. Various pressures had been mentioned for working hydraulic machinery, but after the most ample experience 700-lbs. per square inch had been decided upon by Sir William Armstrong as the best pressure for general purposes, lower pressures involving heavy machines, and higher pressures causing the rams to be so small that sufficient strength could not be obtained without adopting costly expedients. The working of turn tables by hydraulic power was one of the first applications at Paddingdon Station, and again at St. Pancras some 24-feet turn tables had been worked by that system. With regard to the printing of the lecture, he thought it had been too hurriedly



prepared to be suitable for permanent record, but he was quite willing to hand over his notes, and make a reduced copy of the diagrams for the Association, if they desired it. He thanked them for their attention, and for the interest they had shewn in the discussion.

A vote of thanks to the lecturer, and another to the President, which were heartily received and carried unanimously, then closed the proceedings.

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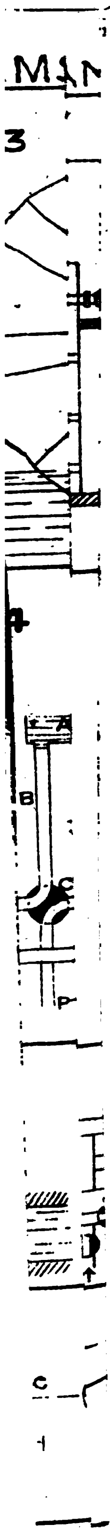
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